Next Generation Use of High Power and Bandwidth in the NE Pacific – A Component of the NSF Ocean Observing Initiative

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Abstract-**This paper will present the unique opportunities of integrating the existing Integrated Ocean Observing System (IOOS) technologies with the capabilities of OOI RSN and the resulting significant enhancement to IOOS HF Radar coverage along the Oregon and Washington coastlines.**

I. Introduction

The National Science Foundation's Ocean Observatories Initiative (OOI) has now been approved for implementation by the National Science Board. The OOI program consists of three elements; the Coastal – Global Scale Nodes (CGSN), the Regional Scale Nodes (RSN), and the Cyber Infrastructure that supports the whole of the Program.

The IOOS Development Plan (Ocean.US, 2005) identified a number of variables that were deemed of high importance for the success and usefullness of a comprehensive ocean observing system. Among those was the measurement of ocean surface currents. The thousands of square kilometers of coastal ocean that are covered by US high frequency radars (HFRs) provide the largest set of ocean current observations in existence. HFR provides the most cost-effective solution to augmenting the existing system of *in situ* measurements and extend its geographic coverage. Recognizing the value of this technology, IOOS partners from state governments, regional associations, and academia have already invested significant resources to purchase radar systems for their regions, ~$55M nationwide and ~$15 million by the State of California alone [1]. The demonstrated societal benefits of coastal HF Radar are magnified when augmented by offshore elements, which can greatly expand the measurement footprint in deep-ocean waters. Improved efficiency for search-and-rescue efforts has been demonstrated with coastal HF radar current mapping by several groups and is presently part of the US Coast Guard search and rescue operations in the mid-Atlantic coastal region, and the expanded system has the potential to save lives and costs in the waters off of Washington and Oregon. Forecasting is improved by assimilation of ocean surface current data into operational numerical models. Other benefits that would be enhanced include oil and hazardous material spill response, water quality monitoring, fisheries operations and research, oceanography research, and vessel surveillance.

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The RSN will consist of seven Primary Nodes offshore in the North East Pacific. Each Primary Node is provisioned with an initial 10gb/s of bandwidth and capable of delivering up to 8 Kilowatts of power. At present the configuration approved by NSF involves two Primary Nodes close to the Juan de Fuca Spreading Center near Axial Sea Mount, two Primary Nodes, one at the base of the continental slope, and one midway up the slope on the so-called “Hydrate Ridge”, an actively venting methane hydrate system. There are two nodes associated with the coastal research being conducted offshore from Newport, Oregon. And finally, there is a Primary Node near the middle of the Juan de Fuca Plate, to the west of Newport. A potential early addition to the approved design would involve implementing complementary offshore HF Radar at or near the RSN Primary Node site close to the mid-Plate Node. The simplest implementation would add a transmit only offshore capability for bi-static operation with the coastal systems.

This unusual addition is quite feasible given the cabled infrastructure that will be in place. Transmit RF power levels exceeding those currently in use in the shore-based installations are possible by taking advantage of the RSN power budget. RSN bandwidth would be providing real time data on a consistent and reliable basis. This “at sea” installation will strongly complement the shore-based systems that are part of the existing and planned national HF radar network through IOOS.

Graphical information demonstrating a significant increase in geographical coverage resulting from this novel offshore deployment of HF Radar capability, as well as a much improved data density is provided.

Implementation cost estimates range from ~ $200K to ~$1M depending on the number and type of HF radars deployed. The specifics of deployment approaches will be developed with vendors and science communities.

II. Societal Benefits

A. Search and Rescue

Of the many benefits to society, the improved life saving results demonstrated by the use of HF Coastal radar data is most significant. U.S. Coast Guard Search and Rescue operations maintain a high success rate for lifesaving, averaging 250 lives saved per year off Oregon and Washington during 1997-2001 [2]. Even so, an average of 20 lives per year were still lost in the region even after notification of the USCG [2]. Improving the reliability of drift trajectories can reduce the search radius required, resulting in shorter times to rescue and improved outcomes. Recently, in May 2009, USCG began using HF radar data operationally for the mid-Atlantic coast as part of its Search and Rescue Optimal Planning System. Investigation is underway as to how to expand this capability to other regions with the help of NOAA IOOS and regional coastal observing systems. See also NOAA News [4].

Off Oregon, surface currents measured with long-range land-based HF radar were evaluated for such an application. A short-term statistical prediction model was developed which used correlations between model winds (North American model, NAM) and measured ocean surface currents, together with forecasts of future winds from NAM, to predict the ocean currents to 48 hours in the future. These forecast currents were then compared with the currents later measured by the HF, and significant skill was found, reducing the required search radii significantly [3].

B. Oil and Hazardous Spill Response

Another application is the analysis of rates of floating oil and pollutants. This is important both after a spill incident, and for environmental impact studies before authorizing offshore operations. An example is the use in the NOAA Office of Response and Restoration’s Emergency Response Division (aka “HAZMAT”) GNOME oil-spill prediction model, where examination of its utility has been underway in recent years [5].

B. Fisheries

Fisheries operations as well as management benefit from knowledge of coastal surface currents, as these influence development of prolific upwelling regions where fish congregate, as well as determine the fates of floating fish egg and larvae to predict future fish stocks and develop early life history dynamics and ultimately spawning success [6]. The economic value of fisheries in the North East Pacific is billions of dollars.

C. Oceanographic Research

Oceanographic research is benefiting immensely from surface current measurements, continuous over space and time, as these reveal coastal processes difficult to study with stationary surface moored sensor platforms. In addition to providing direct observations of time-varying surface circulation, in response to forcing by tides, winds, river outflow and instabilities/advected features, in many coastal regions, HF currents are being assimilated into ocean models, strongly improving their performance in comparison with independent data [7,8].

D. Vessel Surveillance

Finally, these systems are constantly observing vessels passing through their coverage zones; a big advantage is beyond-the-horizon visibility not possible with microwave radars. USCG's drug interdiction and border entry monitoring could be enhanced with improved data.

III. CURRENT INFRASTRUCTURE

This section provides a brief description of the current NANOOS and RSN Infrastructure planned to be in place in the North East Pacific.

A. NANOOS

A growing array of SeaSonde HF surface current mapping systems has been deployed on the coast of the Pacific Northwest continuously since 1997. Spanning the coast from Crescent City, CA (41.8°N) to Long Beach, WA (46.6°N), the present array consists of six long-range systems (5 MHz, 6km range bins, up to 180km range) forming a continuous measurement grid along-coast, and five standard-range systems (12-14MHz, 2km range bins, up to 50km range) concentrated near Newport, Oregon and south of the mouth of the Columbia River. Operated by Oregon State University, the long-range array has become an element of NANOOS, the Pacific Northwest's regional association for IOOS.

Figure 1 shows the approximate ocean surface coverage obtained in standard backscatter operation by the northern four (out of six) long-range systems.

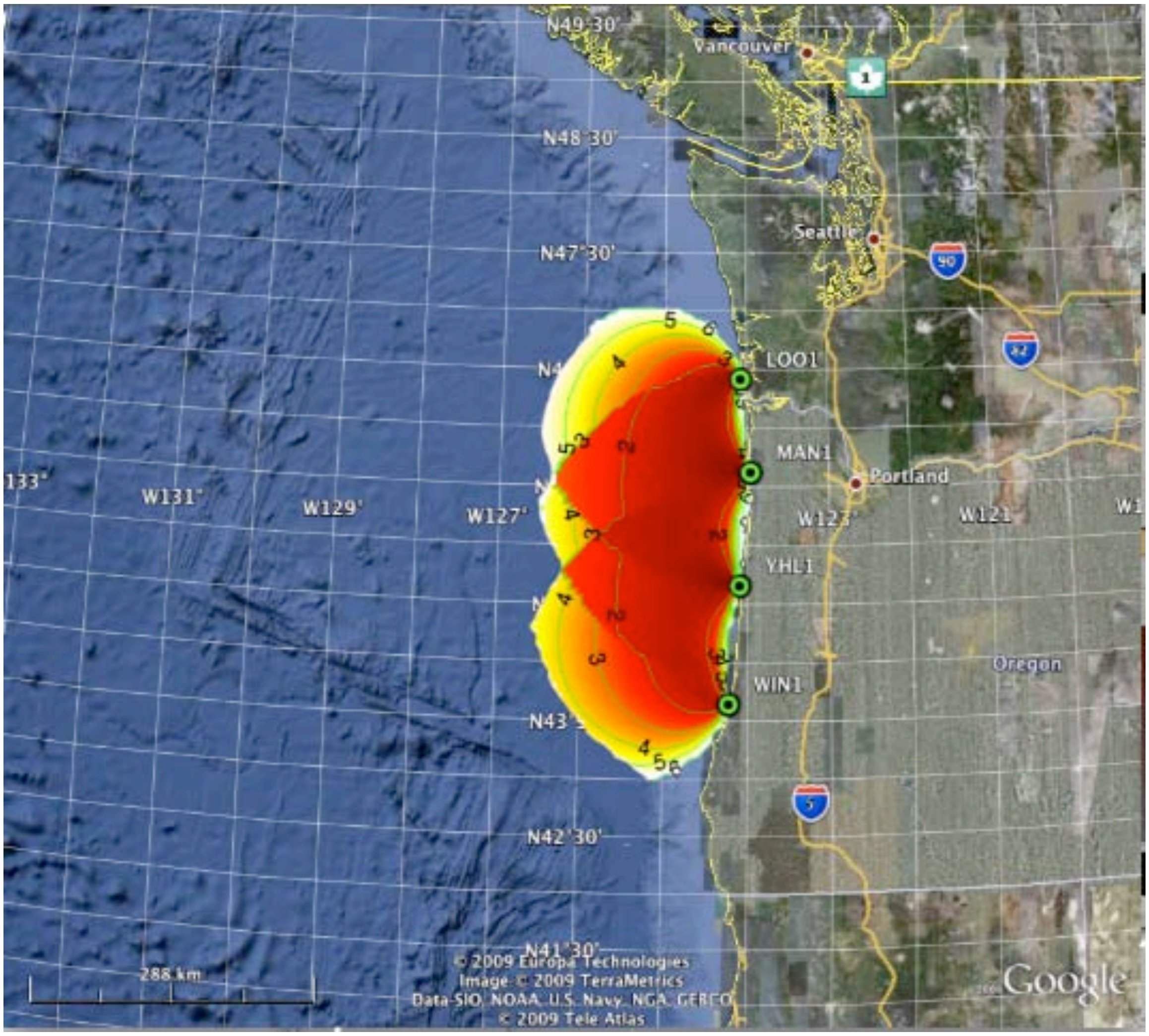


Fig. 1 Northern NANOOS Configuration - The map shows the radial coverage for the northern four (out of six) long-range HF surface current mappers now being operated by OSU in the Pacific Northwest, in standard backscatter mode. In addition to two more long-range systems, the present system has five standard-range sites operating simultaneously, to provide detailed observations near Newport, Oregon and near the mouth of the Columbia River.

B. RSN

The **Regional Scale Nodes** (RSN) form the underwater cabled component of the National Science Foundation's Ocean Observatories Initiative (OOI), which is overseen by the Consortium for Ocean Leadership. The RSN will be constructed over the next five years and will initially support two main science sites off the Oregon/Washington coast at critical locations within the Juan de Fuca plate and in the overlying volume of ocean. The RSN will integrate seamlessly with other parts of the OOI Coastal/Global Scale Nodes and CyberInfrastructure to allow transformational science and education to be conducted by user groups around the world.

The RSN will consist of seven Primary Nodes each capable of 8Kw of electrical power and 10Gb/s of Ethernet bandwidth. RSN, as designed is expandable geographically and in total bandwidth.

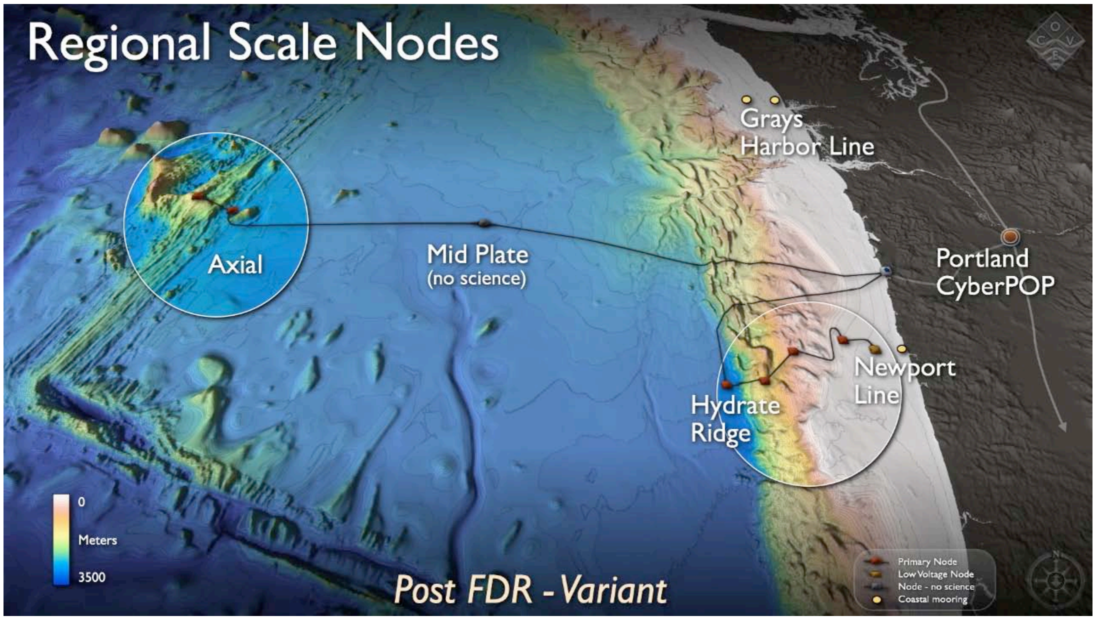


Fig. 2 RSN Geographical Architecture, Primary Infrastructure including terrestrial backhaul and Portland Cyber POP for

The Primary infrastructure operates at 10KV and multiple 10Gb/s Ethernet wavelengths.
The interface with the Secondary Infrastructure occurs at the Primary Nodes where voltage conversion and bandwidth management occurs. The Secondary infrastructure extends the geographic reach and interfaces with the scientific sensors.

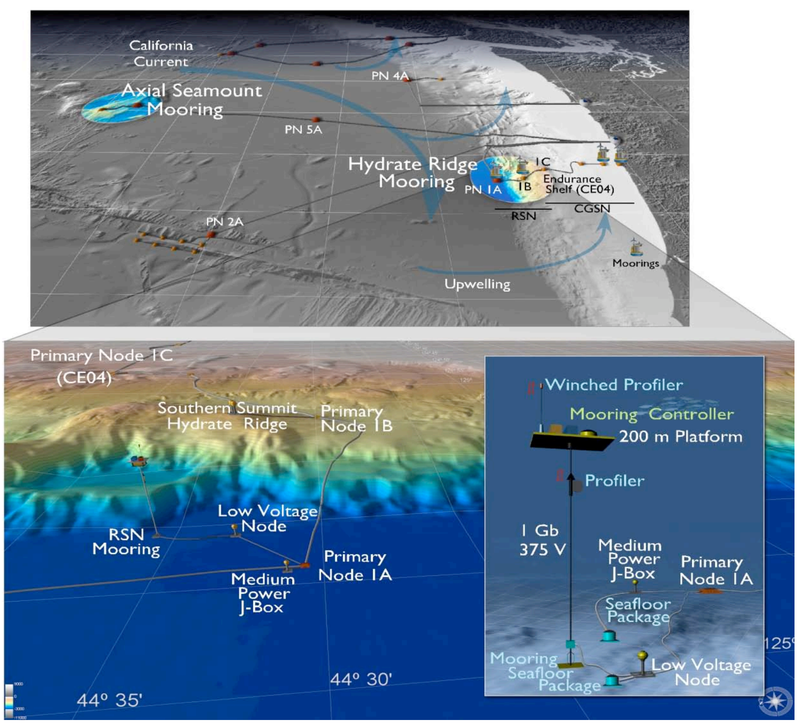


Fig. 3 Secondary Infrastructure, Instrument platforms & Sensors

IV. Concept of Implementation

A. Off Shore – RSN Implementation

The installation of one or more off shore HFR sites is envisioned utilizing common spar buoy implementation and situated within a few kilometers (e.g. <10km) of a primary node. Interconnection to the primary node, or alternatively a Low Voltage Node would supply the required power and bandwidth. Candidate nodes, at the moment, are the RSN Mid-plate node and Hydrate Ridge node.

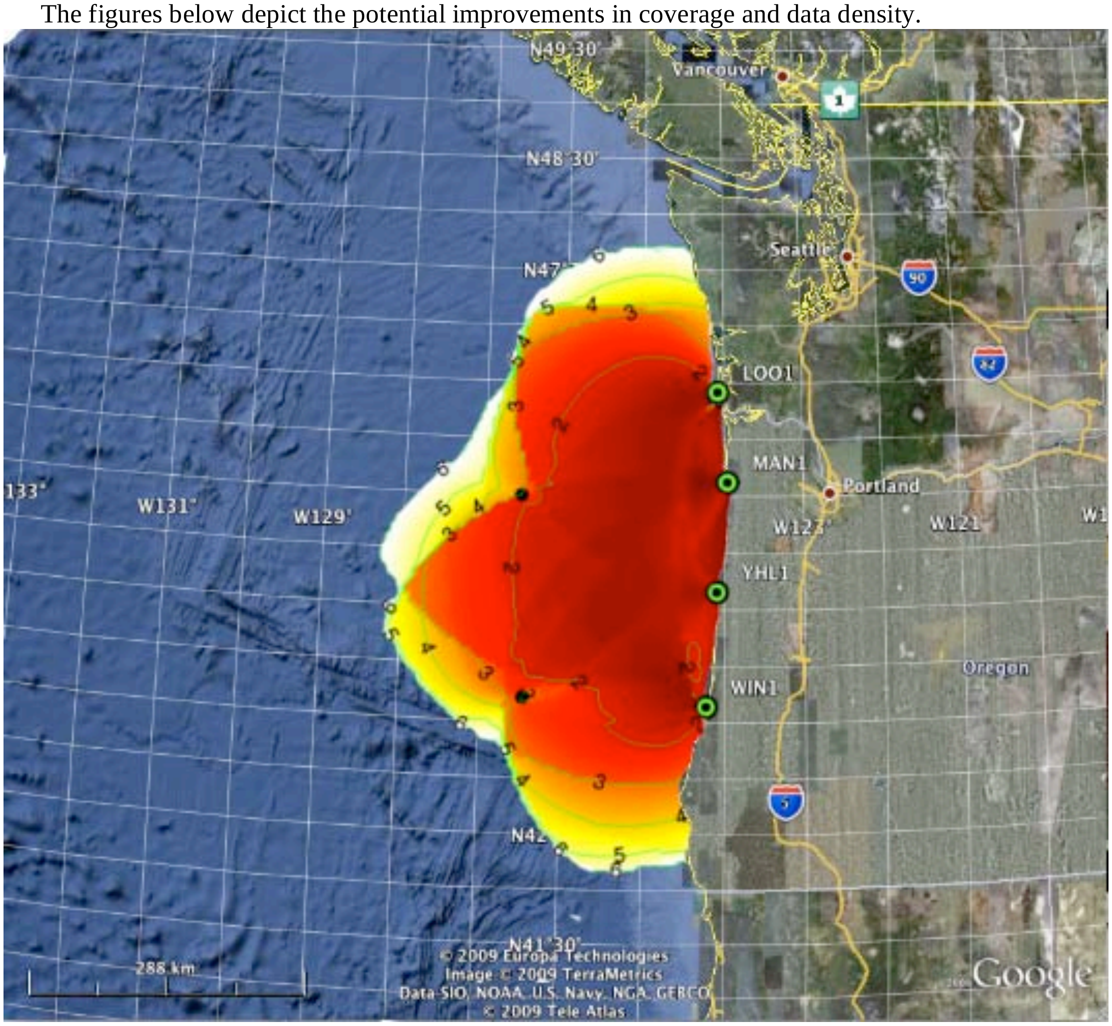
The offshore nodes each would host a transmitter, operated in bi-static mode with the existing shore based sites receiving their scattered signals.

B. Coastal Implementation

As will be seen in the figures below, significant improvement in coverage and data quality is possible without changing the current NANOOS coastal configuration. However additional improvements are possible with upgrades to the shore side HFR sites, allowing them to operate bi-statically among themselves.

C. Improvements

The figures below depict the potential improvements in coverage and data density.



Fig, 4 Two buoys located above RSN with 100watts supplied, operating in bistatic mode – coverage area is doubled

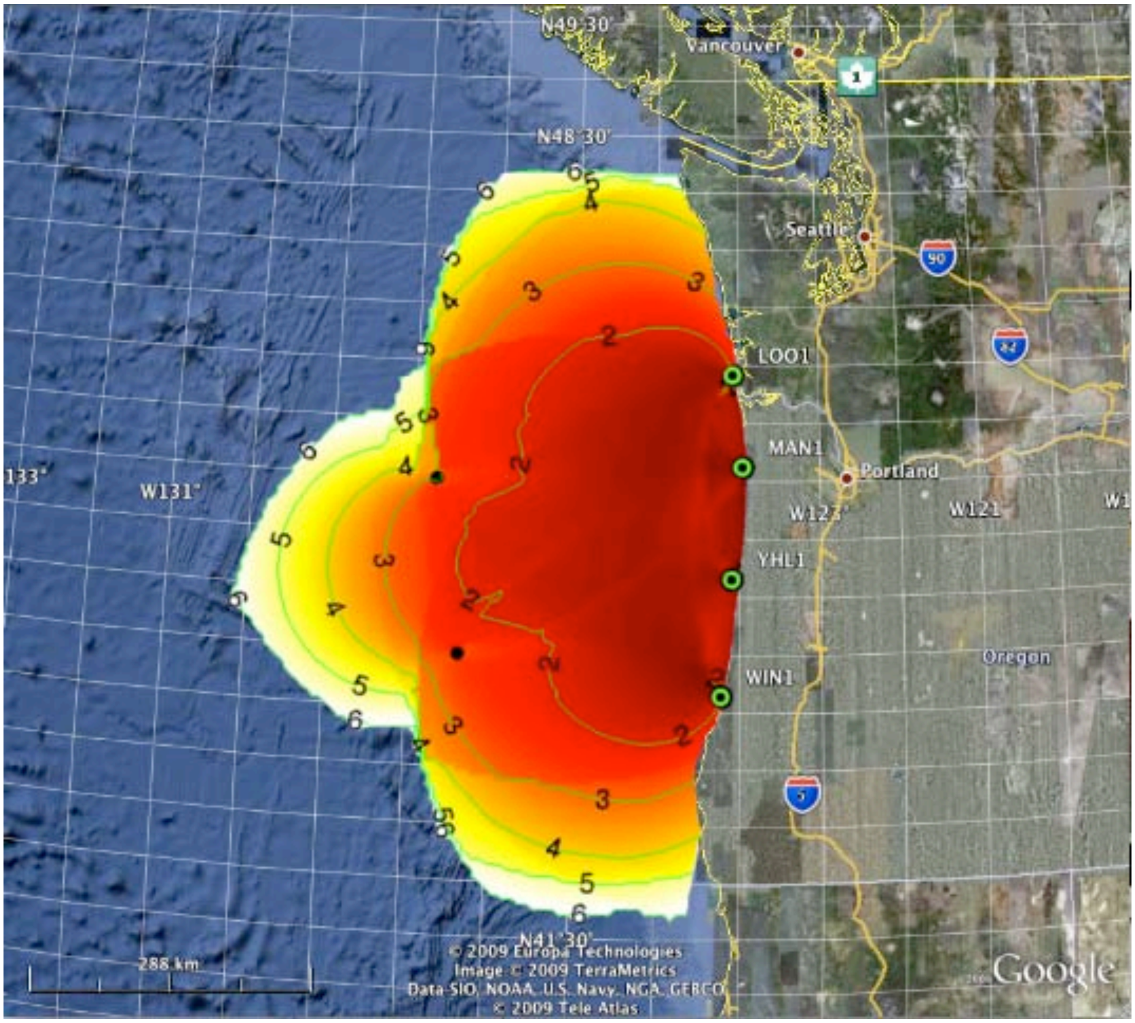


Fig. 5 Two Buoys with 400watts & Coastal Enhancements, coverage quadrupled

V. Summary

This paper is intended to illustrate the potential possible by combining the power and bandwidth available from cabled ocean observatory infrastructure with current and planned IOOS implementations. The societal benefits are highlighted and provide the motivation to continue to further develop and improve the concept as well as seeking other possible implementation locations.

The RSN Team at the University of Washington will continue to collaborate with the NANOOS Operations Team at Oregon State University.

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